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POLYPROPYLENE FIBERS

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POLYPROPYLENE FIBERS

This invention relates to polypr pylene fibers having a novel physical structure.

Heretofore, polypropylene fibers have been limited in acceptance by certain deficiencies in physical properties even though the fibers have attractive low density and low cost. For example, such fibers when employed in the manufacture of fabrics and carpeting possess a waxy, slippery or wet feel thought to result from the presence of low molecular weight polypropylene components within the fiber. Such a feel greatly detracts from the acceptability of the fiber by weavers and carpet makers. With respect to use of polypropylene fibers in carpets, the fibers typically exhibit poor resiliency being readily matted down in use without significant rebound to its original lofty condition.

Significant improvement and minimization of these deficiencies in polypropylene fibers has been accomplished by this invention without need for alteration in the chemical composition of the fiber. In addition, this invention achieves enhancement of the bulk density and flex abrasion of polypropylene fibers.

The polypropylene fiber of this invention has a cross-sectional area, determined normal to the fiber orientation, and a periphery for said cross-sectional area, which periphery possesses at least three (3) sharp angles of not greater than about 90 degrees. The cross-sectional area of the fiber is totally divisible from the center thereof by three imaginary angles of equal size. Each of these divisions are defined to contain at least one of the sharp angles on the periphery within the division.

The unique pr perties of the fibers of this invention in minimizing the wet, waxy or slippery feel typical of conventional polypropylene fibers resides in the fact that the fibers, when bunched together, offer a minimum fiber surface area to touch. Therefore, when one feels a fabric or carpet made of yarns from the fibers having the structure of this invention, the sharp points and angles of the fiber are contacted rather than larger fiber surface areas afforded by round or less angular surfaces possessed by prior art polypropylene fibers. This means that one feels less of the oily, wet, and waxy sensation occurring in the prior art polypropylene fibers because one touches less surface area of the fiber.

The enhanced resiliency of the fibers of this invention is believed to result from the fact that the sharp angles on the surface cause distribution of the fiber mass over a greater area, when viewed from its cross-section taken normal to the direction of the longest fiber axis. When compared to the polypropylene fibers now available, the fiber mass of the structure of this invention is distributed over a greater area and to a greater degree away from the center of the fiber's cross-sectional area. This causes the fiber to have a higher bending moment resulting from greater moment of inertia about the fiber axis.

To illustrate suitable cross-sectional structures embodied within this invention, recourse is made to the accompanying drawing. It is to be understood that the shapes illustrated in the drawing are not intended to limit this invention but are presented solely as examples encompassed by this invention.

Figure 1 illustrates a most preferred cross-sectional structure f a polypropylene fiber. This structure c ntains

three equal, essentially equally spaced, parallel, curved grooves in the fiber surface, each of which at each end terminates at two sharp angles which act to terminate the groove at points along the groove furthest from the center of the cross-sectional area. The angles are separated from each other by the groove and by one of a straight arm and a curved arm thereof. This polypropylene fiber structure has been found to give a most desirable product of unique stability, resiliency, appearance, and feel on hand.

Figure 2 illustrates a cross-sectional structure where the peripheral angles are at a terminal corner of three rectangular-like arms radiating from the center of the cross-section. In this case, the fiber possesses three spaced grooves which are not curved and possess at least one angle at their nadir. Otherwise, the structure of Figure 2 is the same as the structure of Figure 1.

Figure 3 illustrates a variation of the structure of Figure 2 where the distance between the nadir angles is less than the distance between the adjacent angles sharing the same arm which are located further from the center of the cross-section.

Figure 4 characterizes a triangular cross-section coming within the definition of the structure of this invention. Each of the angles of the cross-section may be different or equal and the arms of the triangle may be equal or different.

Figure 5 illustrates a four point star cross-section where the grooves between the points are concave curves. Alternatively, the grooves can be formed by straight lines joining to form an angle at their juncture and at the nadir of the groove.

Figure 6 illustrates a six point star cross-section similar in features to the cross-secti nal structur charact rized

and described with regard to Figure 5.

It is to be appreciated that the fiber structures are produced by conventional wet, dry or melt spinning of polypropylene in a spinneret possessing orifices having essentially the dimensions and configuration of the fiber structure of this invention. Such spinning procedures are well known in the art and form no part of this invention. Illustrative spinning techniques are described in British Patent No. 871,875, U.S. Patent No. 2,939,202, U.S. Patent No. 3,093,444, and particularly U.S. Patent No. 3,048,467.

The specificity of the fiber structure of this invention to polypropylene fibers resides in the advantages and peculiar deficiencies of polypropylene in resin state, particularly molten state, and when it is extruded into a fiber. To illustrate: not all polymers can be extruded through a spinneret orifice possessing a sharp angular corner and still possess the sharp angular corners in the resultant fiber. For example, in Example 1 of U.S. Patent No. 2,939,202, issued June 7, 1960, a polyethylene terephthalate polyester was extruded through a spinneret orifice which was triangular in shape to form a filament having a trilobal cross-sectional structure. The polyester was unable to retain the shape of the orifice because its viscosity characteristics during spinning was too low to prevent flowing out of the angles during extrusion. This is also shown in German Economic Patent No. 11,746, issued July 18, 1956.

The high viscosity of polypropylene is well known, see British Patent No. 871,875 and U.S. Patent No. 3,048,467. Because of this high viscosity, retained during spinning,

polypr pylene fibers may be pr duced having essentially the shape f the spinneret orifice. Thus, polypr pylene represents one of the few fiber forming polymers which can be extruded through an irregularly shaped orifice and retain in the fiber form, essentially the exact shape of the orifice. Thus, the unique facet of polypropylene fibers is that it can be formed with sharp angles on its surface.

However, no advantage exists in doing so unless such enhances the properties of the fiber. Spinnerets possessing the shapes of the cross-sectional fibers of this invention are more difficult to produce and, hence are more expensive. Indeed, polypropylene has been treated in much the same manner as other fiber-forming resins and efforts have been made to provide spinning conditions which allow polypropylene to respond in the same manner as other better known fiber-forming resins. The art has never taken advantage of what has previously been considered a disadvantage to produce a better polypropylene fiber.

The cross-sectional shape of a fiber, if it is to enhance the properties of the fiber, must be specifically designed for the particular fiber in question. Not all cross-sectional shapes lend the same properties to all fibers and not all fibers suffer from the same deficiencies. Thus, it is most surprising that the specific cross-sectional shape of this invention of polypropylene fibers so specifically and desirably improve the suitability of these fibers in many commercial areas, particularly in the use of these fibers in carpeting.

The polypropylene fiber structure of this invention finds its most desirable employment in the manufacture of exceptionally resilient carpets that als possess a most desirable

non-slippery hand. The following illustrat s the advantages of the fiber structure of this inventi n.

Two different fibers were produced; one through a spinneret having an orifice having the shape described in Figure 1 to provide a tri-cavitated fiber having three parallel curved grooves separated by three sharp angular abutments, each provided between two grooves; the other fiber through a standard spinneret having round orifices to produce a cylindrically shaped fiber possessing a round cross section. Sample "A" (the fiber having the cross-sectional shape described in Figure 1) was spun through a spinneret die possessing 60 holes, and Sample "B" (the fiber possessing a round cross section) was spun through a 90-hole spinneret die. Each of the samples possessed 0.15 per cent by weight of the polypropylene resin of titanium dioxide delustering agent. The spinning conditions were as follows:

TABLE I

Sample	Spinning Temperature °C.	Orifice Velocity Feet per Minute	Take-up Velocity Feet per Minute
A	285	4.7	188
B	285	2.7	232

The take-up velocity was the velocity of the fiber as it was removed by the draw-roll from the orifice. Because the take-up velocity exceeded the orifice velocity, the fiber stretched during the drawing operation. The spun yarns from the drawing operation were thereafter stretched at a ratio of 3.5 to 1 with simultaneous annealing at a temperature of 140°C. The stretched oriented polypropylene yarns were thereafter edge-crimped in a conventional manner. The yarns from Sample A were four-plied and the yarns

from Sample B were tw -plied to give ab ut 3800 t tal denier. The denier per filament was about 15 in each case.

The yarns from Samples A and B were tested for single filament flex abrasion, for tactile properties, for fiber resiliency and bulk volume, and for carpet resiliency. The tensile properties of Samples A and B were as follows:

TABLE II

Sample	Total Denier	Tenacity (grams per denier)	Elongation (per cent)	Stiffness Modulus (grams per denier)
A	1060	2.8	31	26
B	1940	3.2	34	28

The fibers were tested for flex abrasion by flex abrading individual deniered filaments on a Fiber Flex Tester produced by Fiber Test, Inc., of Pennsylvania.* In this test, the filaments were flexed over the edge of a bar having a radius of curvature of 0.001 inch. Each filament was loaded at 0.25 gram per denier. The flex-cycles-to-rupture of each filament was recorded by the instrument and the average denier and flex-life (cycles) for the yarn were reported. The temperature and humidity conditions of the test were 24°C. and 47 per cent on the average relative humidity. The results of the test of Samples A and B are described in Table III.

TABLE III

Sample	Flex Cycles to Rupture (Average)
A	62,000
B	23,000

The superior abrasion resistance of Sample A is apparent, clearly indicating the superiority of the fiber shape in this test.

* Grove City, Pennsylvania

The bulk compression of the yarns from Samples A and B were tested by cutting each of the yarns into a staple of one and one-half inches in length and then carding the staple. Specimens of the carded staples weighing 0.222 gram were separated and each was stuffed into a cylindrical mold having a diameter of three-eighths of an inch. The mold was closed by capping and placed in a hydraulic press and the yarn specimen was subjected, at room temperature, to a load of 124,000 pounds per square inch for exactly sixty seconds. After 60 seconds, pressure was released and the yarn specimen, compressed into a pill, was removed. The height of the yarn pill was measured immediately with a compressometer at 1.8 pounds per square inch and then measured after 30 minutes, and thereafter, was again measured after twenty-four hours to determine free recovery time. The results of this test, utilizing Samples A and B, are presented in Table IV.

TABLE IV

Sample	Compressed Plug Height, inch			24 Hr./Immed. Recovery Ratio
	Immediate	30 Min.	24 Hrs.	
A	0.264	0.469	0.523	1.98
B	0.287	0.400	0.453	1.58

The tactile properties of the yarn from Samples A and B, when utilized in a tufted carpet, clearly demonstrated that the carpets made from fibers having the cross-sectional shape of Figure 1 (i.e., from Sample A), which is typical of those shapes described herein as part of this invention, possessed a much drier, considerably less oily or wet feeling and firmer hand.

The bulk volume f the shaped fibers of this invention under low load showed a definite superi rity for the fiber of Sample A over that of Sample B. The bulk volume was determined by taking three grams of one-half to three-quarter inch staple cut of the textured sample fibers and stuffing the fibers in a one hundred-milliliter graduate under a load of 3.1 pounds per square inch. The results of such a test are described in Table V.

TABLE V

Sample	Bulk Volume, cc/g
A	11.1
B	7.3

The resiliency of the fibers of Samples A and B, when employed in a twenty-one ounce per square yard tufted carpet after 1,000 and 20,000 cycles of compression under a ten pound per square inch load, exhibited desirably lower compressibility and better recovery for a carpet made of the fibers from Sample A at both 1,000 and 20,000 cycles. Similarly, recovery of the tufted carpets from twenty-four hours of static compression under ten pounds per square inch load demonstrated the superior resistance to compression of the fibers possessing the cross-sectional structure described in Figure 1 over similar tufted carpet made of polypropylene fibers having a round cross section.

Because of the above results, it is readily apparent that the polypropylene fibers of this invention with their unique cross-section structure possess improved tactile properties, enhanced abrasion resistance, a more desirable bulk volume and a much improved compressional resiliency.

Though the above describes this invention in considerable detail, it is not intended that such sh uld act to limit the invention except to the extent provided by the claims.

WHAT IS CLAIMED IS:

1. A polypropylene fiber having a cross-sectional area, determined normal to the fiber orientation, and a periphery for said cross-sectional area, which periphery possesses at least three sharply-defined angles of not greater than about 90 degrees, said cross-sectional area being totally divisible from the center thereof by three imaginary angles of equal size and each of said divisions from said imaginary angles are defined to possess at least one of said sharp angles on the periphery within the division.

2. A polypropylene fiber having three equal, essentially equally spaced, parallel curved grooves in the fiber surface, wherein each groove at each end terminates in two sharply-defined angles which act to terminate the groove at points along the groove furthest from the center of the cross-sectional area and each of the angles are separated from each other by the groove and by one of a straight arm and curved arm thereof.

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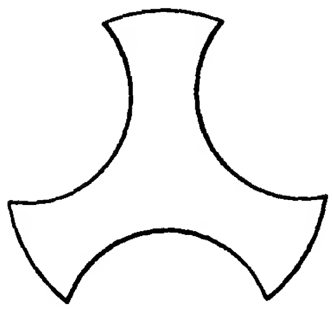

Fig.1.

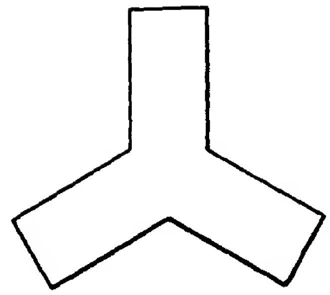

Fig.2.

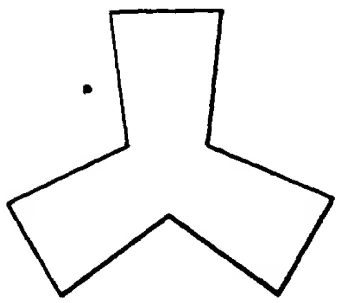

Fig.3.

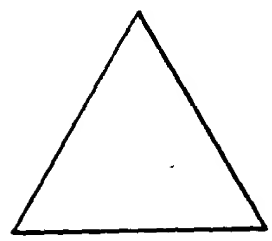

Fig.4.

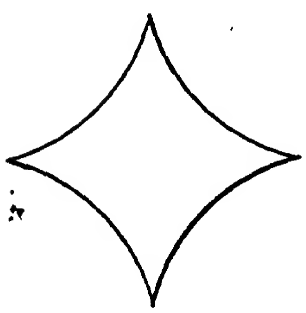

Fig.5.

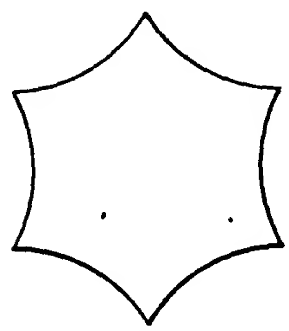

Fig.6.